Attractiveness and Specificity of Pheromone-baited Traps for Male Dogwood Borer, *Synanthedon scitula* Harris (Lepidoptera: Sesiidae)

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ABSTRACT Captures of male dogwood borer, *Synanthedon scitula* (Harris), in traps baited with trinary and binary blends of the female sex pheromone components were compared with those in traps baited with the most effective commercially available lure in apple orchards in West Virginia, Virginia, and North Carolina. Traps baited with the trinary blend [88:6:6 vol:vol:vol (Z,Z)-3,13 octadecadienyl acetate (ODDA):(*E*,*Z*)-2,13-ODDA:(*Z*,*E*)-3,13-ODDA] and the binary blend [96:4 (Z,Z)-3,13-ODDA:(*E*,*Z*)-2,13-ODDA] captured significantly more male dogwood borers than traps baited with the best commercial lure. Although the trinary blend captured the most males, there was no significant difference in captures with the binary blend at all six field sites. Chemical analysis revealed that the commercial lure contained 91.5% (Z,Z)-3,13-ODDA, 7.3% (Z,*E*)-3,13-ODDA, and 1.2% (*E*,Z)-3,13-ODDA, a potent behavioral antagonist of dogwood borer. Species specificity of the trinary and binary blends was very high; >97% of all moths captured were dogwood borer compared with 6–74.4% for the commercial lure. Male dogwood borer showed a concentration-dependent response to traps baited with different source concentrations of the trinary blend at all locations and of the binary blend at most locations. Between 4 and 113 times more male dogwood borers were captured in traps baited with the trinary blend within commercial orchards than within adjacent woodland habitats.

KEY WORDS *Synanthedon scitula*, dogwood borer, sex pheromone, Sesiidae, monitoring traps

THE DOGWOOD BORER, *Synanthedon scitula* (Harris) (Lepidoptera: Sesiidae), has become increasingly problematic in apple orchards in eastern North America, apparently largely because of the increased use of clonal, size-controlling rootstocks in high-density orchards (Riedl et al. 1985, Kain and Straub 2001, Kain et al. 2004, Leskey and Bergh 2005). Leskey and Bergh (2005) showed that burr knots below the graft union on young apple trees propagated on these rootstocks are attacked during the first season after planting, and it is likely that the effects of infestation by dogwood borer are potentially most damaging during the early years of establishment and growth of new orchards.

Despite its increasing prevalence in apple and its historical significance as a pest of deciduous ornamentals (Engelhardt 1932, Eichlin and Duckworth 1988, Johnson and Lyon 1991), particularly dogwood (Pless and Stanley 1967, Potter and Timmons 1983, Williams et al. 1985), our ability to accurately and reliably monitor the seasonal flight and abundance of dogwood borer has been seriously impaired by the poor attractiveness and species specificity of commercially available pheromone lures (reviewed in Bergh and Leskey 2003). Bergh et al. (2004) compared several products in apple orchards in Virginia and West Virginia and reported that the Scenturion dogwood borer lure (Suterra, Bend, OR) was most attractive to and selective for dogwood borer. However, they also concluded that traps baited with Scenturion lures significantly underestimated the size of populations in commercial apple orchards, based on weekly collections of fresh male and female pupal exuviae (Leskey and Bergh 2003).

Recent identification of the female dogwood borer sex pheromone (Zhang et al. 2005), an 88:6:6 (vol:vol:vol) blend of (Z,Z)-3,13-octadecadienyl acetate (ODDA):(*E*,*Z*)-2,13-ODDA:(*Z*,*E*)-3,13-ODDA has provided a powerful new monitoring tool. In field trapping studies, this trinary blend was significantly more attractive to male dogwood borers than a blend of 94:6 (Z,Z)-3,13-ODDA:(*E*,*Z*)-2,13-ODDA, a blend of 94:6 (Z,Z):(Z,*E*)-3,13-ODDA, and the single major component, (Z,Z)-3,13-ODDA, alone. Zhang et al. (2005) also showed that the 94:6 blend of (Z,Z)-3,13-:(*E*,Z)-2,13-ODDA (referred to hereafter as the binary blend) was statistically superior to the 94:6 blend of (Z,Z):(Z,E)-3,13-ODDA and to (Z,Z)-3,13-ODDA

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alone. Furthermore, a geometrical isomer of the main component, (*E,Z*)-3,13-ODDA, was confirmed as a potent antagonist of the behavioral response of dogwood borer males to its sex pheromone.

Use of this information by manufacturers of pheromone lures would enable optimized and standardized pheromone based monitoring of dogwood borer for both research and commercial applications. Indeed, without the application of this information, the continued marketing and use of existing products seems distinctly counterproductive. However, based on current technology, a major constraint to commercializing this pheromone is that the behavioral antagonist, (*E,Z*)-3,13-ODDA, which occurs as a natural by-product of the synthesis of the major component, (Z,Z)-3,13-ODDA, must be reduced to <0.5%. At present, there is no synthetic pathway that will yield (Z,Z)-3,13-ODDA in sufficiently pure form and in commercial volumes, and purification of (Z,Z)-3,13-ODDA contaminated with the antagonist adds time and expense. Certain features of this pheromone do, however, weigh in its favor with respect to commercialization. Zhang et al. (2005) showed that red rubber septa originally containing 1 mg of the pheromone retained >70% of their initial loading after 12 wk in the field. In 2005, trapping studies conducted in five eastern states used one lure per trap for the duration of the flight period (May through October), with no apparent loss of effectiveness (unpublished data). This information suggests that the amount of dogwood borer pheromone per lure may be reduced. Furthermore, for most applications, use of the binary blend may prove to be sufficient, because captures in traps baited with this blend were ≈40–70% greater than those baited with a 94:6 blend of (Z,Z):(Z,*E*)-3,13-ODDA or (Z,Z)-3,13-ODDA alone but only ≈20–25% less than those baited with the trinary blend (Zhang et al. 2005).

Given the present constraints and to adequately address the possibility of commercializing the dogwood borer sex pheromone formulated as a trinary or a binary blend, further information is needed on the relative attractiveness and species specificity of the most effective blends identified by Zhang et al. (2005). In addition, chemical and biological comparisons of these blends with the most effective commercial product reported by Bergh et al. (2004) will further illuminate the requirements for devising a commercially viable approach to optimizing this technology. Here, we report a series of field experiments that further evaluated the trinary and binary pheromone blends as tools for monitoring dogwood borer. Specifically, we compared their attractiveness and species specificity with that of the most effective commercially available product reported by Bergh et al. (2004), conducted chemical analysis to reveal the identity and percentage of compounds that comprise the most effective commercial lure, evaluated the effect of pheromone source concentration of the trinary and binary blends on the capture of males, and used the trinary blend to compare moth captures in commercial apple orchards versus adjacent woodland habitats.

Materials and Methods

Experimental Lure Formulation. (Z,Z)-3,13-ODDA was purchased from Bedoukian Research (Danbury, CT; ≈90% purity) and purified by flash column chromatography using 2:10 of CH_2Cl_2:hexane as the mobile phase on 15% $AgNO_3$ in silica gel 60 (230–400 mesh; EM Science Gibbstown, NJ). The fractions with <0.3% of the impurity, (*E,Z*)-3,13-ODDA, were combined and solvents were evaporated. (*E,Z*)-2,13-ODDA and (Z,*E*)-3,13-ODDA (>96% purity) were purchased from Pheromone Bank (Wageningen, The Netherlands). Purities of chemicals were checked on a 60-m polar DB-WAXETR GC capillary column (Jew Scientific, Folsom, CA) before preparing the lures for the field study.

Red natural rubber septa (5 mm; Wheaton, NJ) were loaded with 1 mg (standard loading rate for commercial lures) of (Z,Z)-3,13-ODDA alone or in combination with (*E,Z*)-2,13-ODDA and/or (Z,*E*)-3,13-ODDA in ≈20 μl of hexane solution. The same amount of solvent (hexane) was loaded on the septum for the blank control. After loading, the solvent was allowed to evaporate in a fume hood for 30 min. Lures were wrapped in aluminum foil and shipped to each cooperator in 20-ml plastic vials by express courier. All lures were held at −10°C until deployed.

Field Sites. Field tests were conducted in West Virginia, Virginia, and North Carolina between May and October 2004 in commercial apple orchards that consisted of trees on size-controlling rootstocks and that exhibited active dogwood borer infestations. All orchards were managed for disease and arthropod pests according to standard practices followed in each state, although no insecticides specifically targeting dogwood borer were applied. Experimental lures were deployed in Pherocon 1C (all experiments in West Virginia and North Carolina) or Delta sticky traps (all experiments in Virginia; Trécé, Salinas, CA) placed in trees at a height of ≈1.22 m above the ground (Riedl et al. 1985).

Lure Comparisons. The first comparison included the following experimental treatments: the trinary blend, the binary blend [94:6 (Z,Z)-3,13-ODDA:(*E,Z*)-2,13-ODDA], the Scenturion dogwood borer lure (lot 56U03119), the most effective commercially available lure for dogwood borer (Bergh et al. 2004), and a blank control. At each orchard, the four treatments were randomized within each of five rows that were separated by at least one buffer row, and traps were spaced at a minimum of ≈25-m intervals within a row. Traps within the five replicates were rotated among positions within each row at weekly intervals for the duration of each test. The number of dogwood borer, peachtree borer and lesser peachtree borer, and other male Sesiidae captured were removed and recorded weekly. Traps were deployed from 28 May to 26 October at National Fruit, Inwood, WV, from 26 May to 25 October at Orr Bros., Arden, WV, from 26 May to 13 October at Cedar Creek Grade and Relief, VA, and in North Carolina from 11 May to 22

Table 1. Mean ± SE male dogwood borers captured in traps ($N = 5$) baited with the trinary blend, binary blend, or the Scenturion dogwood borer lure in each of two commercial apple orchards in West Virginia, Virginia, and North Carolina

Lure	Inwood, WV	Arden, WV	Cedar Creek Grade, VA	Relief, VA	Nix, NC	Davis, NC
Trinary blend	728.8 ± 109.8a	469.6 ± 106.6a	866.4 ± 159.7a	548.0 ± 132.0a	291.4 ± 44.1a	762.4 ± 75.7a
Binary blend	555.8 ± 99.2a	419.2 ± 90.2a	654.4 ± 122.1a	451.2 ± 86.2a	234.4 ± 62.5a	547.6 ± 63.4a
Scenturion	2.0 ± 0.6b	2.2 ± 0.7b	3.6 ± 0.7b	13.6 ± 4.2b	15.6 ± 6.1b	39.8 ± 9.5b

Mean within columns for each orchard location followed by the same letter are not significantly different according to Tukey's HSD test at $P \leq 0.05$.

June at Nix and 13 May to 8 July at Davis. For each location, data comparing captures of male dogwood borer in traps baited with the trinary blend, the binary blend, or commercial lure were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's honestly significant difference (HSD) (SAS Institute 2001). Dependent variable data were not transformed, because the homogeneity-of-variance assumptions were met in all cases, according to Bartlett's test. Data from control traps were omitted from the analyses presented here because of zero trap catches. Species specificity of experimental blends and the commercially available lure were determined based on the percentage of male dogwood borer, peachtree/lesser peachtree borer, and other Sesiidae captured in traps baited with each lure treatment at each location.

Commercial Lure Analysis. Five Scenturion dogwood borer lures, lot 56U03119 (Suterra), were introduced individually into a 4-ml vial containing 3 ml hexane and soaked for 3 h. Extracts (20 μl each) were diluted with hexane to an approximate volume ($\approx$10 ng/ul), and 3 μl was used for pheromone component analysis. Electronic impact (EI) gas chromatography–mass spectrometry (GC-MS) analyses of pheromone were conducted on a Hewlett–Packard (HP) 6890 GC coupled to a HP 5973 Mass Selective Detector using an DB-WAXETR capillary column (J&W Scientific, Folsom, CA; 60 m by 0.25 mm ID, 0.25-μm film thickness, 120°C for 2 min, then programmed to 230°C at 15°C/min and held for 15 min) with helium as carrier gas. A 70-eV electron beam was used for sample ionization. The identities of (Z,Z)-3,13 ODDA, (*Z,E*)-3,13 ODDA, and (*E,Z*)-3,13 ODDA in the Scenturion lure were confirmed by co-injection with (*Z,E*)-3,13 ODDA and (*E,Z*)-3,13 ODDA standards.

Pheromone Source Concentration. The effect of pheromone source concentration of the binary and trinary blends was evaluated in orchards in each state. Trinary blend source concentrations included 0.01, 0.10, 0.30, 1.00, and 10.00 mg, whereas source concentrations of the binary blend included 0.01, 0.10, 0.30, 0.50, and 1.00 mg. Trap deployment and maintenance protocols were as described for the previous test. Three replicates per orchard of the trinary blend series were deployed from 14 June to 26 July at National Fruit, Inwood, WV, from 8 July to 12 August at Cedar Creek Grade, VA, and from 6 July to 24 August at Nix, NC. Similarly, three replicates per orchard of the binary blend series were deployed from 6 September to 25 October at Orr Bros., Arden, WV, from 9 September to 7 October at the AHS-AREC, VA, and in North Carolina from 9 September to 11 October. Comparisons of captures in traps baited with different source concentrations of the trinary and binary blends were analyzed using one-way ANOVA followed by Tukey's HSD (SAS Institute 2001) for each location. Dependent variable data were not transformed, because the homogeneity-of-variance assumptions were met in all cases, according to Bartlett's test. For each location, source concentration of the binary and the trinary blends was used as the independent variable and regressed against total trap captures of male dogwood borers, peachtree and lesser peachtree borers, and other sesiid species to determine the concentration response relationship using a linear regression model (SAS Institute 2001).

Captures Within and Outside Orchards. Dogwood borer populations within and outside commercial orchards were evaluated using traps baited with lures containing 1 mg of the trinary blend. At each location, one trap was deployed 50 m within an apple orchard and another was placed 50 m inside a wooded habitat immediately adjacent to the orchard. Traps were deployed from 9 August to 7 September at Orr Bros., Arden, WV, from 9 August to 15 September at Jefferson Orchards, Kearneysville, WV, from 3 August to 7 September at three locations in Frederick Co., VA, and from 7 August to 9 September at two locations in North Carolina.

Results

Lure Comparisons. Significantly more male dogwood borers were captured in traps baited with the trinary and binary blends compared with the Scenturion dogwood borer lure in commercial apple orchards in Inwood, WV ($F = 19.74$, df = 2,12, $P = 0.0002$), Arden, WV ($F = 10.13$, df = 2,12, $P = 0.0026$), Cedar Creek Grade, VA ($F = 15.01$, df = 2,12, $P = 0.0005$), Relief, VA ($F = 9.78$, df = 2,12, $P = 0.0030$), Nix, NC ($F = 10.81$, df = 2,12, $P = 0.0021$), and Davis, NC ($F = 41.95$, df = 2,12, $P < 0.0001$; Table 1). The trinary blend captured the greatest number of dogwood borer males: 19–364 times more than the commercial lure across locations.

The species specificity of the trinary and binary blends was high. Male dogwood borer represented 97.1–99.2 and 97.8–99.2% of all captures with the trinary and binary blends, respectively (Fig. 1). In contrast, the Scenturion dogwood borer lure was much

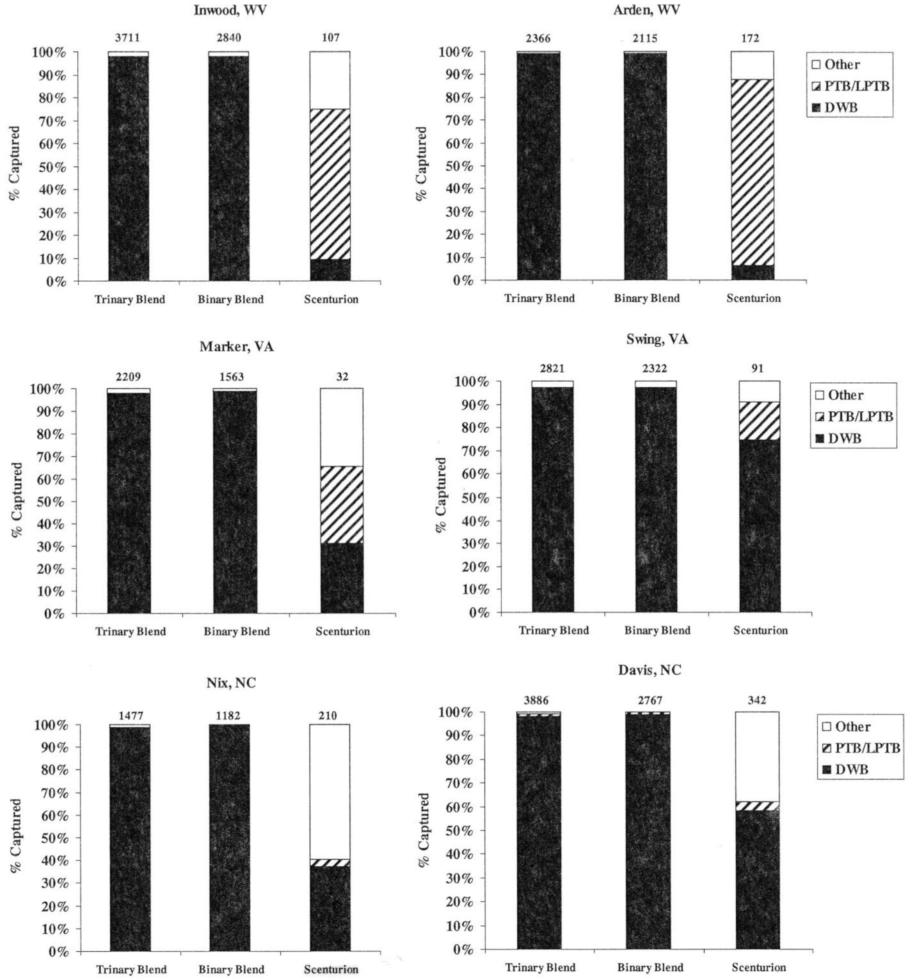

Fig. 1. Percentage of captures comprised of dogwood borer, peachtree and lesser peachtree borer, and other male Sesiidae in traps baited with the trinary blend, the binary blend, or the Scenturion dogwood borer lure in 2004. Number above each bar is the total number of moths captured in five traps baited with each lure.

less species-specific; the percentage of captures comprised of dogwood borer ranged from 6.3% in Arden, WV, to 74.4% in Swing, VA (Fig. 1). Most of the captures in traps baited with the Scenturion lure were peachtree and lesser peachtree borer males at Inwood, WV (65.4%), and in Arden, WV (81.3%). At the Nix location in North Carolina, captures of other species included the lilac/ash borer, *Podosesia syringae* (Harris), and *Paranthrene* spp., which accounted for 59.5% of the captures.

Commercial Lure Analysis. Chemical analyses of the compounds extracted from Scenturion dogwood borer lure revealed that lures were comprised of 91.5% (*Z,Z*)-3,13-ODDA, 7.3% (*Z,E*)-3,13-ODDA, and 1.2% (*E,Z*)-3,13-ODDA (potent antagonist of dogwood borer).

Pheromone Source Concentration. Lures containing from 0 to 10 mg of the trinary blend produced significant linear relationships between pheromone source concentration and capture of male dogwood borers in West Viriginia (F = 8.77, P = 0.0415, r^2 = 0.69), Virginia (F = 18.32, P = 0.0006, r^2 = 0.53), and North Carolina (F = 8.89, P = 0.0407, r^2 = 0.69); capture of peachtree and lesser peachtree borers in Virginia (F = 6.58, P = 0.0207, r^2 = 0.29); and capture of other species in West Virginia (F = 167.89, P = 0.0001, r^2 = 0.91), Virginia (F = 103.46, P = 0.0001, r^2 = 0.87), and North Carolina (F = 313.20, P = 0.0001, r^2 = 0.95). Among pheromone loadings, significantly more male dogwood borers were captured in traps baited with the 10-mg lure compared with 0.01-mg and control lures in West Virginia (F = 5.67, df = 5,12, P = 0.0065) and with the 0.30-, 0.10-, and 0.01-mg and control lures in Virginia (F = 29.78, df = 5,12, P < 0.0001) and North Carolina (F = 12.01, df = 5,12, P = 0.0002; Table 2). No peachtree and lesser peachtree borer males were captured in West Virginia, and very few captures were recorded in Virginia and North Carolina (Table 2). Significantly more males of other sesiid species were captured in traps baited with a

Table 2. Mean ± SE male dogwood borers, peachtree and lesser peachtree borers, and other sesiid species captured in traps baited with lures containing 0.01–10.00 mg of the trinary blend ($N = 3$) and in traps baited with lures containing 0.01–1.00 mg of the binary blend ($N = 3$) deployed in West Virginia, Virginia, and North Carolina in 2004

	Dose (mg)	Trinary blend			Dose (mg)	Binary blend		
		WV (14 June to 26 July)	VA (8 July to 12 Aug.)	NC (6 July to 24 Aug.)		WV (6 Sept. to 25 Oct.)	VA (9 Sept. to 7 Oct.)	NC (9 Sept. to 11 Oct.)
Dogwood borer	10.00	305.0 ± 66.1a[1]	193.3 ± 25.7a	384.3 ± 58.2a	1.00	27.3 ± 13.3a	30.7 ± 4.3a	213.7 ± 52.8a
	1.00	149.3 ± 51.5ab	158.7 ± 11.3a	265.6 ± 91.0ab	0.50	27.3 ± 5.2a	15.3 ± 2.2b	202.7 ± 42.3a
	0.30	157.3 ± 50.0ab	73.3 ± 21.9b	114.0 ± 23.8bc	0.30	33.3 ± 10.3a	19.3 ± 4.8ab	127.3 ± 42.0ab
	0.10	129.0 ± 54.7ab	42.3 ± 4.9bc	32.7 ± 19.4c	0.10	10.3 ± 2.4a	8.7 ± 1.5bc	22.3 ± 12.8b
	0.01	24.7 ± 11.1b	6.0 ± 3.5bc	1.3 ± 1.3c	0.01	0.0 ± 0.0a	0.0 ± 0.0c	0.3 ± 0.3b
	0.00	0.0 ± 0.0b	0.0 ± 0.0c	0.0 ± 0.0c				
Peachtree and lesser peachtree borer	10.00	—	0.7 ± 0.7a	0.3 ± 0.3a	1.00	—	—	—
	1.00	—	0.0 ± 0.0a	0.0 ± 0.0a	0.50	—	—	—
	0.30	—	0.0 ± 0.0a	0.3 ± 0.3a	0.30	—	—	—
	0.10	—	0.0 ± 0.0a	0.0 ± 0.0a	0.10	—	—	—
	0.01	—	0.0 ± 0.0a	0.0 ± 0.0a	0.01	—	—	—
	0.00	—	0.0 ± 0.0a	0.0 ± 0.0a				
Other	10.00	8.7 ± 1.5a	13.3 ± 2.6a	14.3 ± 1.8a	1.00	—	—	—
	1.00	0.0 ± 0.0b	3.0 ± 1.5b	2.7 ± 0.3b	0.50	—	—	—
	0.30	0.7 ± 0.3b	0.0 ± 0.0b	0.3 ± 0.3b	0.30	—	—	—
	0.10	0.3 ± 0.3b	0.7 ± 0.3b	0.3 ± 0.3b	0.10	—	—	—
	0.01	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.01	—	—	—
	0.00	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b				

Mean within columns for each orchard location followed by the same letter are not significantly different according to Tukey's HSD test at $P \leq 0.05$.

Table 3. Total no. and percentage (%) of male dogwood borers captured 50 m within and 50 m outside commercial apple orchards in wooded habitat in West Virginia, Virginia, and North Carolina

Location	Sample interval	Total number (%) 50 m within orchard	Total number (%) 50 m within woods
Arden, WV	9 Aug. to 7 Sept.	567 (79.3)	148 (20.7)
Kearneysville, WV	16 Aug. to 15 Sept.	651 (83.3)[a]	130 (16.7)
AHS-AREC, VA	3 Aug. to 7 Sept.	683 (99.9)	6 (0.1)
Woodbine, VA	3 Aug. to 7 Sept.	809 (92.6)	64 (7.4)
Relief, VA	3 Aug. to 7 Sept.	76 (96.2)	3 (3.8)
Nix, NC	7 Aug. to 9 Sept.	552 (92.6)	44 (7.4)
MHCRS, NC	7 Aug. to 9 Sept.	142 (99.3)	1 (0.7)

[a] Total captures and (%) in traps from 23 Aug. to 15 Sept. that include a trap placed 100 m within woods are as follows: at 50 m within the orchard = 527 (80.3%), at 50 m within woods = 114 (17.3%), and at 100 m within woods = 15 (2.2%).

10-mg lure in West Virginia ($F = 30.90$, df = 5,12, $P < 0.0001$), Virginia ($F = 18.09$, df = 5,12, $P < 0.0001$), and North Carolina ($F = 56.01$, df = 5,12, $P < 0.0001$) compared with all other source concentrations (Table 2).

Lures containing from 0.01 to 1 mg of the binary blend also produced significant linear relationships between pheromone source concentration and capture of male dogwood borers in Virginia ($F = 17.34$, $P = 0.0252$, $r^2 = 0.85$) and North Carolina ($F = 11.53$, $P = 0.0426$, $r^2 = 0.79$) but not in West Virginia ($F = 2.30$, $P = 0.2269$, $r^2 = 0.43$). Among pheromone loadings, significantly more males were captured in traps baited with the 1-mg lure compared with 0.50-, 0.10-, and 0.01-mg lures in Virginia ($F = 12.30$, $P = 4,10$, $P = 0.0007$) and North Carolina ($F = 7.54$, df = 4,10, $P = 0.0045$; Table 2). In West Virginia, results of the one-way ANOVA were significant at $P = 0.0692$ ($F = 3.05$, df = 4,10). No other sesiid species were captured in these trials.

Captures Within and Outside Orchards. Across all locations where traps were deployed simultaneously 50 m within commercial apple orchards and 50 m within adjacent woodland habitats, 79.3–99.9% of all male dogwood borers were captured in apple orchards (Table 3).

Discussion

Identification of the complete blend of dogwood borer sex pheromone (Zhang et al. 2005) has led to a tremendous improvement in the attractiveness and reliability of lures compared with previous studies in which commercial lures were used (reviewed in Bergh and Leskey 2003). Based on total trap captures across all locations, the trinary and binary blends evaluated in this study caught approximately 40 more dogwood borer males compared with the Scenturion dogwood borer lure (Table 1). The marked increase in attractiveness of these new formulations compared with the Scenturion dogwood borer lure was likely caused by the presence of (*E,Z*)-3,13-ODDA in the commercial product. This compound had been described as a potential antagonist to the capture of male dogwood in some studies (Karandinos et al. 1977, Greenfield 1978, Warner and Hay 1985) but not others (Snow et al. 1985). In the laboratory, Zhang et al. (2005) found that the electroantennogram (EAG) response of male Dogwood borer (DWB) antennae to (*E,Z*)-3,13-ODDA (0.30 ± 0.03 mV) was as strong as to (Z,Z)-3,13-ODDA (0.30 ± 0.10 mV), the major component of its sex pheromone (both of which were the strongest responses recorded). Furthermore, in field trials, as little as 0.5% (*E,Z*)-3,13-ODDA added to the trinary pheromone blend significantly reduced trap captures. (Zhang et al. 2005). Scenturion lures deployed in studies reported here contained ≈1.2% (*E,Z*)-3,13 ODDA; this impurity was reduced to <0.3% in our trinary and binary blend formulations. Tumlinson (1979) discussed the difficulty in synthesizing specific ODDA compounds with high levels of geometric isomeric purity and stated that development of new synthetic pathways leading to greater purity were being pursued. However, such novel synthetic pathways have yet to be developed, and it is currently impossible to produce a large amount of purified (Z,Z)-3,13-ODDA economically.

Zhang et al. (2005) reported that traps baited with the trinary blend caught significantly more dogwood borers than those baited with the binary blend in field experiments. In results reported here, we observed numerically but not statistically greater captures in traps baited with the trinary blend compared with the binary blend at all six field locations. Experiments reported by Zhang et al. (2005) were conducted over 6–12 wk, whereas those reported here were conducted for up to 17 wk, thus leading to greater potential for fluctuations in population numbers and increased variability contributing to lack of statistical differences between treatments. It should be noted that the third component in the trinary blend, (*Z,E*)-3,13-ODDA, was never detected in pheromone gland extracts of female dogwood borer and only detected in some of the effluvial collections (Zhang et al. 2005). In electroantennogram studies, male dogwood borer antennae did respond to (*Z,E*)-3,13 ODDA (Nielsen et al.1979, Zhang et al. 2005). However, the binary blend also is extremely attractive to dogwood borers and was significantly more attractive than the major component (Z,Z)-3,13 ODDA alone or a 94:6 (Z,Z):(Z,E)-3,13 ODDA formulation (Zhang et al. 2005).

Selectivity of pheromone lures is a critical factor in optimizing their effectiveness as monitoring tools. Interspecific and intergeneric attraction to geometrical isomers of 3,13-ODDA is common among many sesiid species (Nielsen et al. 1975, Snow et al. 1985, Rogers and Grant 1990, Meyer and Cranshaw 1994, Braxton and Raupp 1995, Pfeiffer and Killian 1999, Bergh et al. 2004). Among the commercial products compared by Bergh et al. (2004), the Scenturion dogwood borer lure was the most species-specific, capturing the greatest number of dogwood borers and fewest peachtree and lilac borers. The percentage of dogwood borers captured in traps baited with the Scenturion lure ranged from 33 to 86% among the test locations. Here, we report a marked improvement over those results. The percentage of dogwood borers captured with the trinary and binary blends was >97% across all locations, whereas the specificity of the Scenturion lure for dogwood borer was much lower, ranging from 6.3 to 74.4% of total trap captures. Although the data are not presented, the species specificity of the main dogwood borer pheromone component, (*Z,Z*)-3,13-ODDA, and a 94:6 blend of (*Z,Z*): (*Z,E*)-3,13-ODDA also were evaluated. Again, species specificity was very high, with >92% of all captures comprised of dogwood borer across all locations (unpublished data). Traps baited with commercial lures for dogwood borer frequently capture large numbers of peachtree borers (Bergh et al. 2004). In our studies, captures of peachtree borers were very low, comprising between 0 and 1% across all locations (Fig. 1). Even at a higher pheromone source concentration of the trinary blend, captures of peachtree borers and other sesiid species remained extremely low (Table 2). We did not capture any other sesiid species in traps baited with various pheromone source concentrations of the binary blend, likely because the trials were conducted late in the season after some species were no longer active, but based on results from the 1-mg lure (Fig. 1), we can reasonably presume that very few other species would be captured at higher pheromone source concentrations.

Dogwood borer has the broadest host range of any of the sesiids and has been documented on at least 19 species of woody plants in 10 families (Engelhardt 1932, Eichlin and Duckworth 1988, Johnson and Lyon 1991). Numerous studies have reported capturing it in pheromone traps in both managed and native habitats (Rogers and Grant 1990, Braxton and Raupp 1995, Pfeiffer and Killian 1999, Eliason and Potter 2000), and we assume that native host plants are common in wooded areas near commercial apple orchards in West Virginia, Virginia, and North Carolina. However, when traps baited with the trinary blend were deployed within apple orchards and in adjacent woodlands, the vast majority of moths were captured in orchards (Table 3). While these data suggest that the population density of dogwood borer was much lower in woodlands surrounding commercial apple orchards than in the orchards themselves, additional work on the abundance, distribution, and seasonal phenology of dogwood borer in its different habitats is needed.

The improved monitoring capability afforded by the identification of the components comprising the dogwood borer sex pheromone should assist apple growers and researchers alike in developing pest management programs. Although the trinary blend captured the greatest number of dogwood borers, captures in traps baited with the binary blend were statistically equivalent and equally species specific. The binary blend may prove to be a more economically viable formulation for commercial companies to produce, based on the difficulty of synthesizing specific ODDA compounds with high levels of isomeric purity. Furthermore, behaviorally based management strategies using sex pheromones, such as mating disruption for peachtree and lesser peachtree borers (Gentry and Snow 1984, Pfeiffer et al. 1991, Agnello and Kain 2002) and mass trapping for apple clearwing moth, *S. myopaeformis* (Trematerra 1993, Bosch et al. 2001) in Europe can now be explored for dogwood borer as well.

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